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Practices to increase probability of success in Process Automation Systems implementation given complexity factors in Industrial Megaprojects

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Practices to increase probability of success in Process Automation Systems implementation given complexity factors in Industrial Megaprojects

by

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Dedication

To my wife Sandra, for all incredible support she always was willing to provide during the time being dedicated to this research.

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Abstract

Practices to increase probability of success in Process Automation Systems implementation given complexity factors in Industrial Megaprojects

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The University of Texas at Austin, 2013

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Process Automation Systems' design, selection, planning and implementation play a contributing role in achieving success in Industrial Megaprojects within the Oil and Gas Industry. Process Automation Systems represent only 8% - 10%[1] of the total installed cost in capital projects, but the reliability and performance of Process Automation Systems are fundamental factors to ensure the operability and safety of new plants within the oil and gas industry.

Recent studies show an increasing number of Industrial Megaprojects in execution during the last decade, a better understanding of the real impact that these projects can bring to our societies, the complexity of these endeavors and the likelihood of having more megaprojects being approved during the next 20 years in the global

[1] Griffith, Russell. "Chevron's use of the Main Automation Contractor Strategy to Deliver Global Standardization", ARC Forum, February 10, 2010: 7.

market. It is pleasant to hear that there are favorable conditions present in the industry to promote and execute capital projects, but there is an alarming rate at which these capital projects overrun schedules and budgets.

Project execution key performance indicators such as cost growth, cost index, schedule index, schedule slippage and operability index often applied to measure the success of Megaprojects, should be carefully followed by project management teams, during the implementation of Process Automation Systems.

In the oil and gas industry megaprojects are executed in a stage gated work process typically divided into phases with a pause for assessment and decision about whether to proceed. The gate assessments examine both economic/business and technical aspects of the project, to make decisions to stop, recycle or proceed. The purpose of this research is to identify practices in a stage gated work process approach (FEL Front End Loading) to increase the probability of success in Process Automation Systems implementation given complexity factors in Industrial Megaprojects.

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Industrial Megaprojects

The US Federal Highway Administration defines megaprojects as major infrastructure projects that cost more than US$1 billion, or projects of a significant cost that attract a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment and budgets. [2]

Industrial Megaprojects are very large and complex projects executed typically with a total capital cost of more than $1 billion (US dollars) that demand a huge task force and resources to completion. Because of size and complexity, these projects have become much more difficult to manage. This research refers to industrial megaprojects in the Oil & Gas process industries. It focuses on the implementation of Automation Systems in Oil & Gas industrial megaprojects.

During the last two decades there have been many more megaprojects than in times past, and this will continue for decades to come. Industrial megaprojects are important to the societies, in which they are being done, important to health of the global economy and they are important to the sponsors investing huge amounts of money.[3]

COMPLEXITY

As observed by Edward Merrow[4] in his recent publication "Industrial Megaprojects: Concepts, Strategies and Practices for Success" projects in the Oil & Gas industry have increased in size and complexity for a number of reasons:

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[2] J. Richard Capka, "Megaprojects – They Are a Different Breed", Public Roads Magazine, Jul/Aug Vol 68 No 1, 2004, http://www.fhwa.dot.gov/publications/publicroads/04jul/01.cfm

[3] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc.: 2011), 293.

[4] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc: 2011), 11.

- Easily accessed resources close to markets have largely been depleted.
- International oil companies must venture into deep water and other difficult environments because national resource holders control more easily developed oil and gas.
- Chemical companies seeking lower costs feed stocks need to exploit economies of scale to compete globally and often must go to the source of feed stocks to make the project viable.

Existing research in megaprojects performance and success suggests:

- The physical and economic scale of today's megaprojects is such that whole nations may be affected in both the medium and long term by the success or failure of just a single project.[5]
- Such enormous sums of money ride on the success of megaprojects that company balance sheets and even government balance of payments accounts can be affected for years by the outcomes. The success of these projects is so important to their sponsors that firms and even governments can collapse when they fail.[6]

NATURE OF MEGAPROJECTS

Edward W. Merrow describes the nature of these endeavors in a realistic approach: Megaprojects are messy. There will be problems, even if everything possible has been done to prepare the project.[7] Megaprojects are problematic. Historically

[5] Bent Flyvbjerg, Nils Bruzelious and Werner Rothengatter, Megaprojects and Risk: an anatomy of ambition, (Cambridge University Press, 2003), 4.
[6] Bent Flyvbjerg, Nils Bruzelious and Werner Rothengatter, Megaprojects and Risk: an anatomy of ambition, (Cambridge University Press, 2003), 4.
[7] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc: 2011), 293.

megaprojects are failing at an alarming rate. Megaprojects are responsible directly and indirectly for millions of jobs around the world.

MEASURING SUCCESS - HOW TO MEASURE SUCCESS?

Independent Project Analysis (IPA) a global research and consultant company utilizes five dimensions to benchmark megaprojects success: cost overruns; cost competitiveness; slip in execution schedules; schedule competitiveness and production versus plan.[8]

Cost overruns are measured as the ratio of the actual final costs of the project to the estimate made at the full funds authorization (sanction) measured in escalation, adjusted terms.

Cost competitiveness measures how much the project spent relative to other projects with similar scopes.

Slip in execution schedules is measured from the start of detailed engineering until mechanical completion of facilities. Slip is defined as the actual schedule divided by the schedule forecast at full funds authorization.

Schedule competitiveness is the length of the execution relative to similar projects.

Production versus plan measured against the actual production versus the intended production. IPA classifies a project as a failure in this dimension only if it was experiencing severe technical problems that continued well into the second year after startup.

[8] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc: 2011), 38.

IPA Megaprojects database with more than 300 global megaprojects shows that 65 percent of industrial projects with budgets larger than $1 billion in 2010 US dollars failed to meet business objectives.[9] In IPA database the average project cost is $3.2 billion and took 43 months to execute, the execution time measured as the time from full funds authorization to completion of all facilities. The average cycle time measured from start of scope development through the startup, averaged 66 months and took more than 10 years in a number of cases. These projects are very problematic and are failing at an alarming rate. [10]

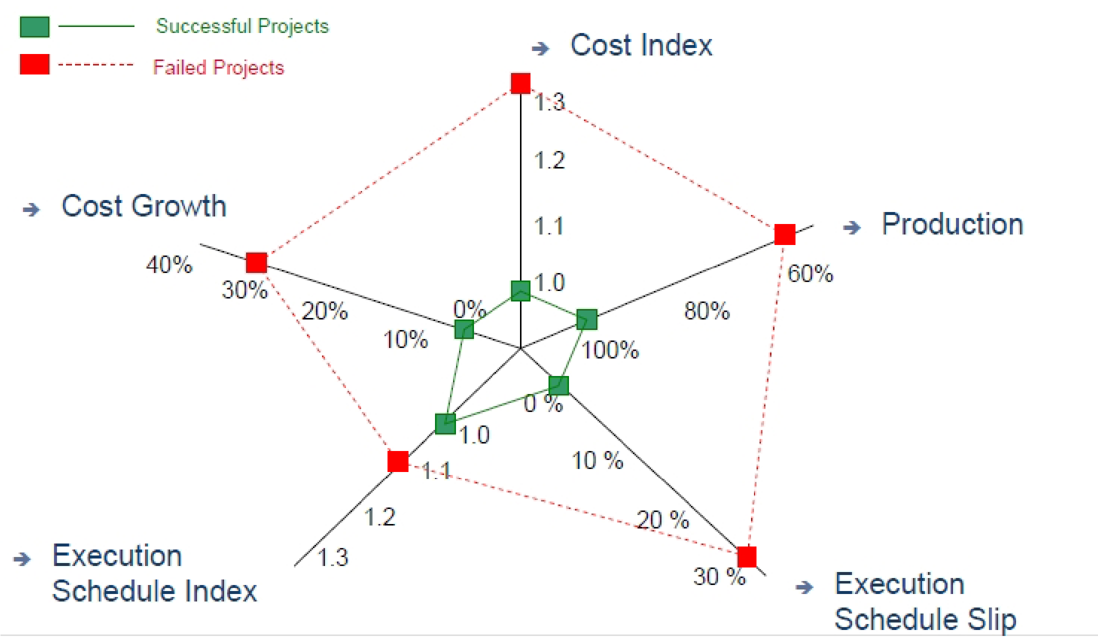

Figure 1: Contrasting successful and failed projects.[11]

[9] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc: 2011), vii.
[10] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc: 2011), 27-30.
[11] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc: 2011), 48.

The area of interest of this research is the successful implementation of automation scope in Megaprojects. Raymond Teaster and Dave Adler in the article "Successfully managing projects"[12] presented benchmarking results from more than 100 automation projects that revealed that less than 20 percent of projects were actually able to achieve their goals in the scope, schedule and budget. That means that, according to Teaster and Adler's research, when a company decides to embark on an automation project, there is an 80 percent chance it will fail to do what the company intended, be delivered later than expected.

Recent studies indicate that seventy five percent of companies ranked on-time completion of projects as the number one of success criteria. However, 91.7 percent of the respondents reported that their projects were finished late. New plants and expansions are taking too long to commission, there is poor handover to operations, and sub-optimal operations once the plants are commissioned. Everyone is very busy trying to figure out how to manage these risks but one thing is constant, refining executives are still demanding project, operations and business results without excuses. Traditional project execution is not getting the job done.[13]

More has to be done to identify practices to increase the probability of success within the Automation discipline in Industrial Megaprojects from the engineering, procurement and construction (EPC) standpoint. Within the EPC jargon, the Automation discipline is sometimes referred as Instrumentation and Controls discipline. Because of the size and complexity of Megaprojects, the automation scope normally includes thousands of elements each one of them requiring definition, design, selection, procurement, installation and commissioning. The Automation scope is as a set of work

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[12] R Teaster, D. Adler, "Successfully Managing Projects", Intech Magazine (July/August 2013): 28.

[13] Honeywell White Paper, "Integrated Main Automation Contractor (I-MAC) for Refining", November 2007.

packages within the WBS (Work Breakdown Structure) in a Megaproject, the success of the development and implementation should be consequently evaluated under the five dimensions shown in figure No 1.

CAUSES OF FAILURE

According to IPA the study of causes of failure of megaprojects and its results are based on statistical analysis of a good sample of international projects executed in the past. Common root causes of megaprojects failure identified by IPA include:

- Inaccurate or incomplete basic technical data[14].
- Schedules set far too aggressively at the outset.
- A large number of major changes occur during execution[15].
- Cost overruns due to lack of realism in initial cost estimates. The length and cost of delays are underestimated, contingencies are set too low, changes in project specifications and designs are not sufficiently taken into account, changes in exchange rates between currencies underestimated or ignored, so is geological risk, and quantity and prices are undervalued as are expropriation costs and safety and environmental demands.
- Many major projects also contain a large element of technological innovation with high risk. Such risk tends to translate into cost increases, which often are not adequately accounted initial cost estimates.[16]

[14] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc: 2011), 21.
[15] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc: 2011), 44.
[16] Bent Flyvbjerg, Nils Bruzelious and Werner Rothengatter, Megaprojects and Risk: an anatomy of ambition, (Cambridge University Press, 2003), 12.

PROJECT CONTEXT

Project teams and stakeholders should be aware of the context in which megaprojects will be executed. In most cases for these projects the job site is located oversees and in remote locations. The execution phase will involve international contractors, subcontractors, Engineering, Procurement and Construction Contractors (EPCs) and other suppliers with engineering centers distributed around the world. Failure results when the context is not adequately assessed or when major changes are unanticipated.[17] The assessment of context in which a megaproject will be executed should consider obtaining information in following key context areas:

- The Physical Location
- History of Prior Projects in the Area
- The nature and perceived value of the physical environment
- The Political and Institutional Environment
- Regulatory Climate and Stability
- Local Content Requirements
- Social, Religious and Cultural considerations
- Local labor availability and quality
- Competing Projects

Typically Instrumentation and Control scope represents 8% to 10 % of the project Total Installed Cost (TIC) in industrial megaprojects.[18] Instrumentation and Control

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[17] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc: 2011), 59.

[18] Griffith, Russell. "Chevron's use of the Main Automation Contractor Strategy to Deliver Global Standardization", ARC Forum, February 10, 2010: 7.

design/commissioning activities are often critical path, however, and can represent a significant portion of the project risk.[19] The automation system should never be on the critical path with proper planning and execution.[20]Although a relatively small portion of the overall investment in new processing facilities, automation systems can have a large impact on a successful outcome and on maximizing the return of the investment throughout the facility's lifecycle.[21]

PROCESS AUTOMATION SYSTEMS IN MEGAPROJECTS

The Process Automation System (PAS) refers to a computer based implementation of the control and information functions necessary to operate and manage a specific industrial process. The PAS is used to automatically control a process in the Oil and Gas industry. Process Automation Systems in Megaprojects include thousands of field instruments, communications between field devices and the control processors; control networks, human machine interfaces (HMIs) and several sub systems to safely run an industrial process, and to protect against upsets and failures within the process. Subcomponents of a typical Process Automation System for a 300K Barrels per day refinery are shown in table 1.

[19] Griffith, Russell. "Chevron's use of the Main Automation Contractor Strategy to Deliver Global Standardization", ARC Forum, February 10, 2010: 7.

[20] Russell, Griffith, MAC and Automation Services Section (ARC World Industry Forum: February 2010): 8.

[21] Honeywell, "Integrated Main Automation Contractor Concept and FEED Services", Service Note, Dec 2007.

Table 1: Typical Subsystems in a Process Automation System

Item	Subsystem Description
1	BPCS: Basic Process Control System, in most cases a Distributed Control Systems (DCS) is used
2	Safety Instrumented System (SIS)
3	Fire and Gas System (FGS)
4	Packaged Equipment
5	Analyzer Systems
6	Operator Training System (OTS)
7	Burner Management System (BMS)
8	Advanced Process Control System (APC)
9	Compressor Control Systems (CCS)
10	Machine Monitoring System (MMS)
11	Regulatory Blend Control (RBC)
12	Advanced Blend Control (ABC)
13	Field Instrumentation
14	Tank Gauging System (TGS)
15	Custody Transfer Systems (Fiscal Metering)
16	Plant Information Network (PIN)
17	Wireless Communication System
18	Control Buildings, Remote Instrument Buildings
19	Closed Circuit Television System (CCTV) for process monitoring

Figure 2 shows a Process Automation or Control System Network topology for a particular process unit. In Industrial Megaprojects, which normally consist of multiple process units, several control networks will be part of the Process Automation System. Figure 3 categorizes the tasks carried out by the industrial control system for a complete plant or company.

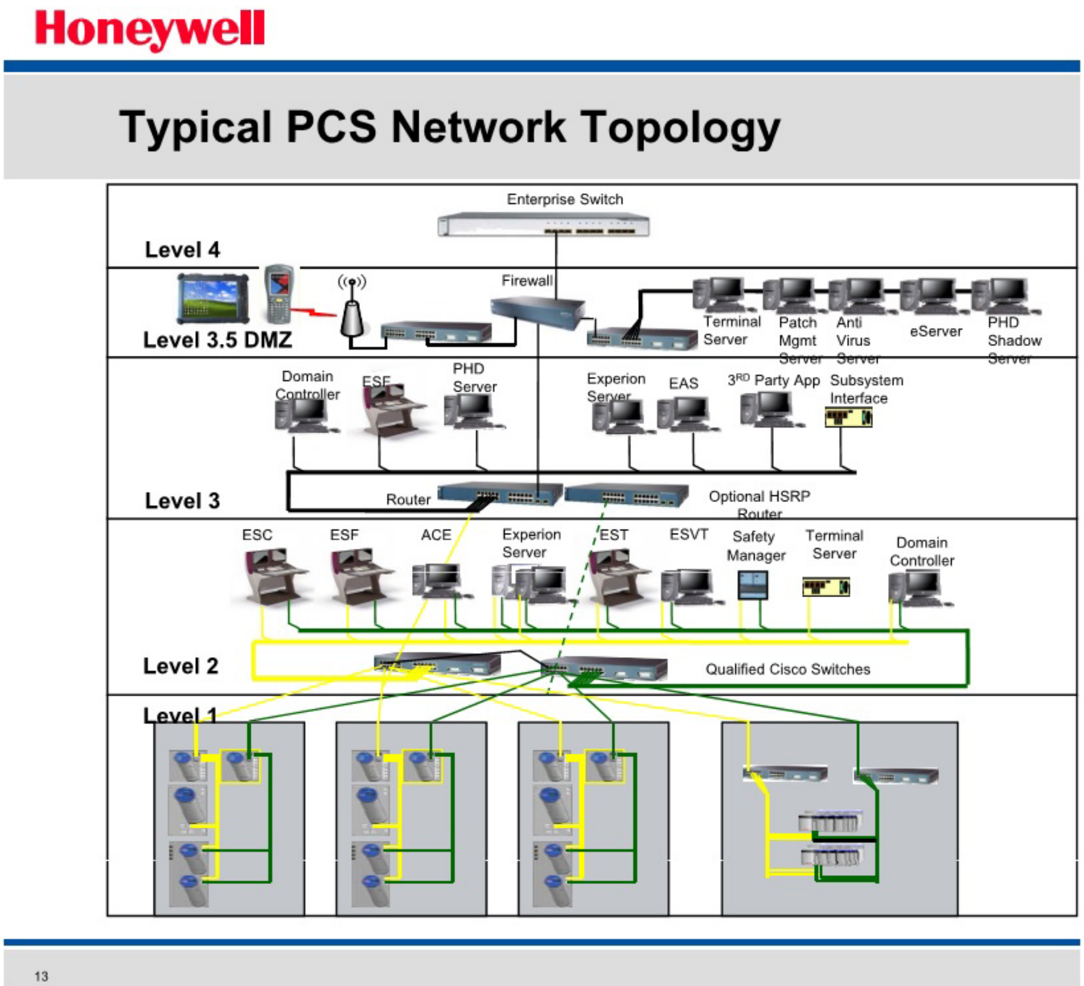

Figure 2: Process Automation or Control System Network Topology[22]

22 R. Alston, "Process Control Networks: Secure Architecture Design", Honeywell, 2013: 13.

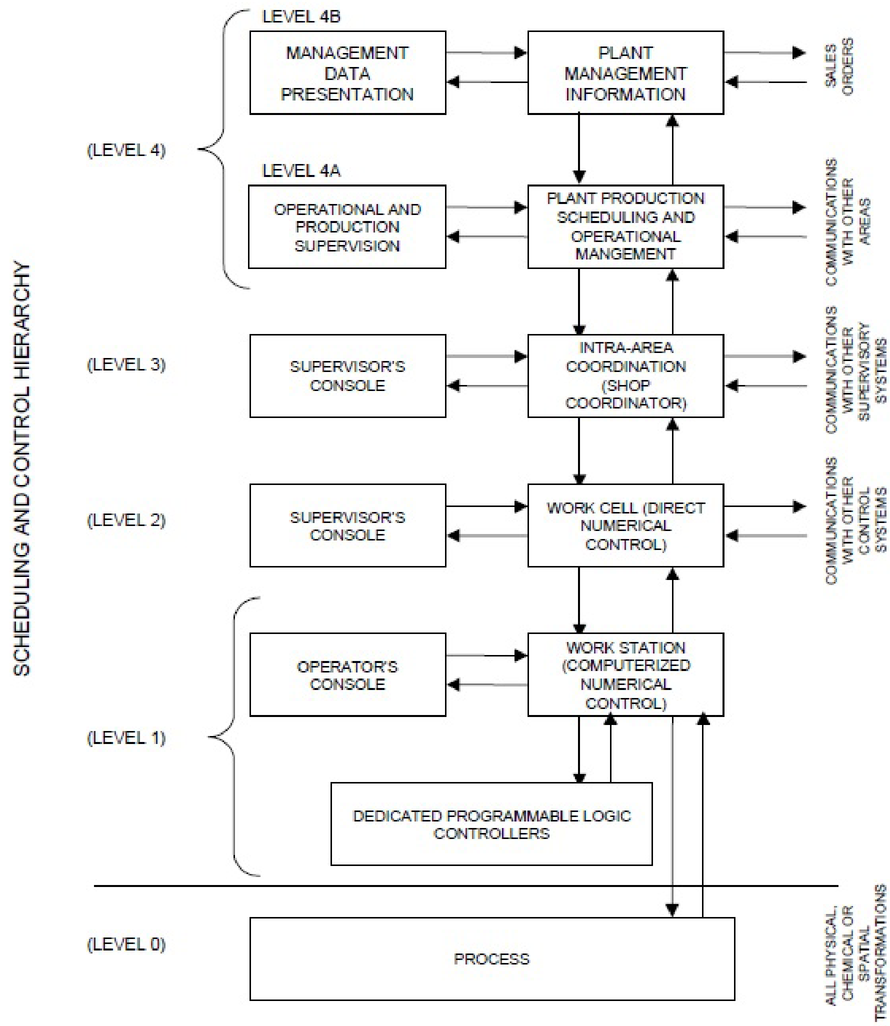

Figure 3 Hierarchical Computer Control Structure for a large Manufacturing Complex[23]

[23] ANSI/ISA-95.00.01-2000, "Enterprise-Control System Integration Part 1: Models and Terminology", July 2000: 96.

Two megaprojects in the Oil & Gas industry during the last decate that were endeavours of extreme complexity in the design and execution phases for Process Automation Systems are: The Reliance Industries Ltd. Export Refinery Project at Jamnagar, India and the BP Whiting Refinery Modernization Project (WRMP) at Whiting, Indiana USA. These two projects have been developed by multiple synchronized EPCs all with engineering centers distributed arround the world.

When Becthel (Engineering, Procurement and Construction Contractor) completed the Reliance Jamnagar complex in northwest India, it was the largest refinery and petrochemicals complex ever built from the ground up. The project included the construction of a second refinery at the site with a capacity of 580,000 barrels per day, along with a 600 megawatt power plant and enhanced port facilities. The final project cost totaled more than US$6 billion.[24]

Figure 4: Jamnagar Refinery Project. PAS HMI in Main Control Building.

[24] Bechtel, "Jamnagar Refinery", May 2007, http://www.bechtel.com/jamnagar_refinery_expansion.html.

On the second refereced project, BP (International Oil and Gas Company) is investing several billion dollars to modernize its Whiting Refinery in Northwest Indiana. The WRMP is the largest, most complex refining project undertaken in BP's recent history. The Whiting Refinery Modernization Project ("WRMP") increases the refinery oil processing capability by reconfiguring the largest 3 crude distillation units and adding new coking capacity and associated processing units.[25]

[25] BP, "Whiting Refinery Modernization Project", http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/W/WRMP.pdf

Front End Loading (FEL)

FRONT END LOADING MODEL

In the Oil & Gas Industry megaprojects are executed using the Front-End Loading (FEL) model. FEL is defined as the process of developing sufficient strategic information with which the owners can address risk and make decisions to commit resources in order to maximize the potential for a successful project. FEL is also known as front end planning, pre project planning, feasibility analysis, conceptual planning, programming/schematic design, and early project planning.[26]

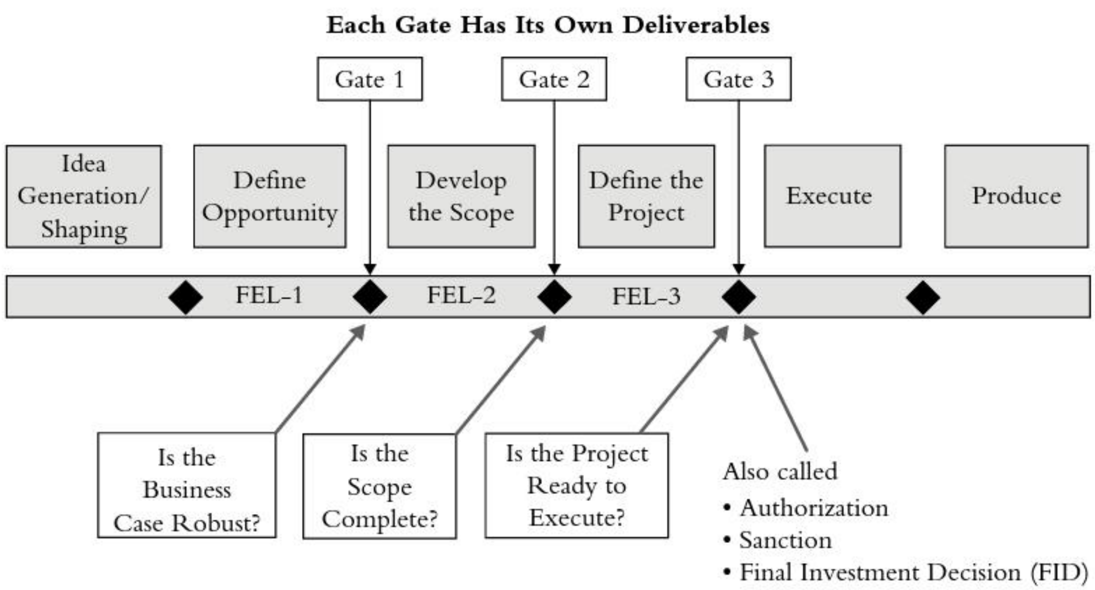

Figure 5: Front End Loading Model (FEL). [27]

[26] Construction Industry Institute (2012). "Improving Project Performance". CII Best Practices Guide ver. 4: page 17.
[27] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc.: 2011): 203.

FEL is the core work process of project teams prior to authorization. The work process is typically divided into phases or stages with a pause for an assessment and decision about whether to proceed. The gate assessments should examine both the economic / business and technical aspects of the project at that point. In the three phase format shown in figure 5, the first gate FEL-1 is designed to produce an inspection and evaluation of the health of the business case for the capital project. The second stage FEL-2 develops and articulates the scope of a project to a point where we can be confident that all elements of scope are accounted for. The third stage FEL-3 is all about preparation to execute the project. It is about filling in all of the details. All items that were rated preliminary at the end of FEL-2 need to become definitive (complete and final) at the end of FEL-3.[28]

The project execution phase is where 95 percent of the money will be spent, and typically execution will occupy about 60 percent of a megaproject's total cycle time as measured from the start of scope development through startup. Figure 3 shows the relationship of project expenditures and influence of decisions made during the early stages of a project. Decisions made during the FEL will have a greater impact on final project costs than decision made during the execution phase. Project management and all stakeholders should be aware of the impact of decisions throughout the total project cycle.

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[28] Edward W. Merrow, Industrial Megaprojects: Concepts, Strategies and Practices for Success (Wiley John Wiley & Sons, Inc.: 2011), 202-215.

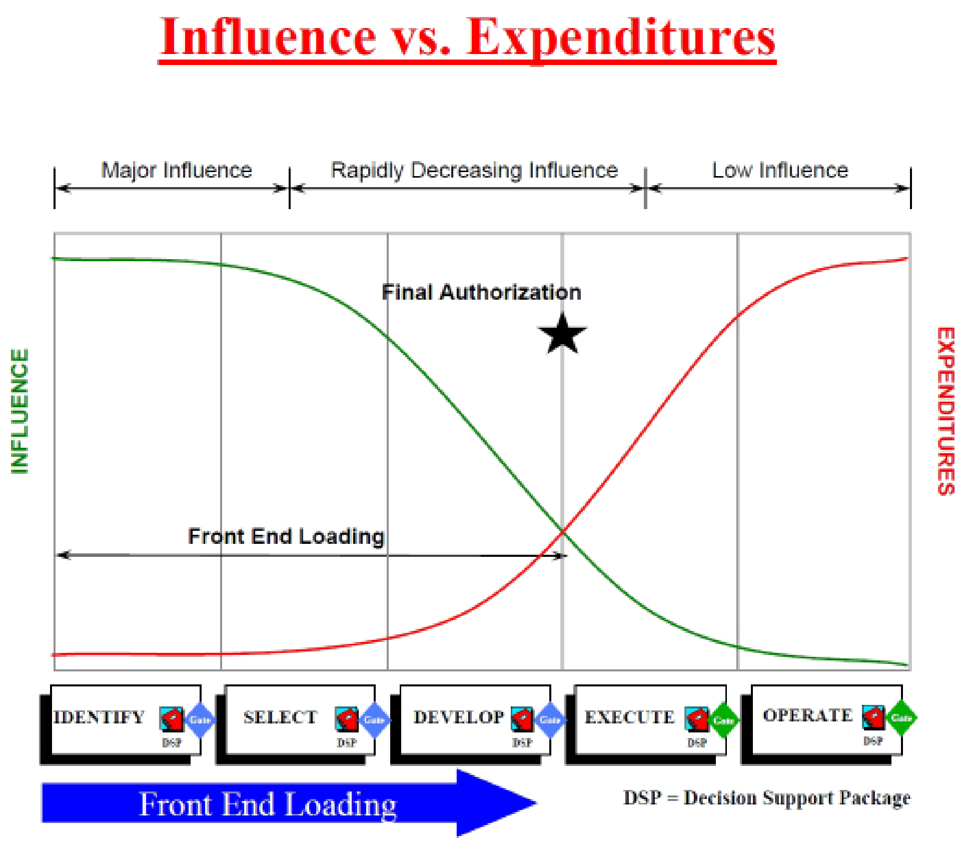

Figure 6: Influence vs. Expenditures.[29]

PROJECT MANAGEMENT

Project Management is the discipline of planning, organizing and managing resources to bring about the successful completion of specific project goals and objectives.[30] The large number of activities should be well planned, organized, managed and properly allocated to project members for an efficient execution and successful project completion. Because of the size of mega projects, owners of the facilities chose a project management execution model including a Project Management Consulting team, multiple EPC Contractors and a Main Automation Contractor. Reliance Industries and

[29] Lavingia, N. "Business success through Excellence in Project Management (Better, Cheaper, Faster and Safer Projects)": 14.
[30] D.W. Choi, Understanding basic project management, Practice the four basic elements to ensure a successful outcome, Hydrocarbon Processing, December 2008: 65.

BP Megaprojects referenced in Chapter 1 were executed with multiple EPC contractors working in collaboration with a Main Automation Contractor (MAC).

SCOPE MANAGEMENT

Every project operates under the triple constraint (cost, scope, time), but on megaprojects the problem is magnified by the massive scope, scale and duration. The concept of triple constraint is based on the premise that if any one of the elements changes, this may have an impact on the other two. Careful analysis of these three factors must be done on every project and every contract with the project to identify the solution that has the least undesirable impact.[31] Figure 2 highlights the interrelationship between these three elements and the influences on these elements.

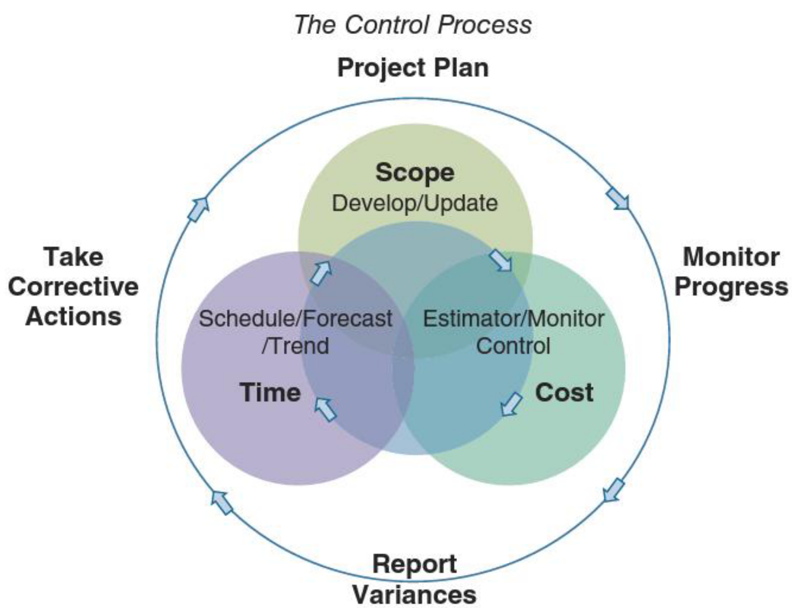

Figure 7: The control process.[32]

[31] V. Greiman, "Megaproject Management, Lessons on Risk and Project Management from the Bid Dig", John Wiley &Sons, 2013: 153.
[32] V. Greiman, "Megaproject Management, Lessons on Risk and Project Management from the Bid Dig", John Wiley &Sons, 2013: 153.

The elements of scope definition can vary from project to project, in large scale projects the scope should be totally defined before entering the execution phase. The PMBOK Guide focuses on the six processes described in the first two columns of Table 1 as essential to scope management.[33]

Table 2: Scope Processes

Process	The PMBOK Guide
Plan scope management	Documenting how the scope will be defined, validated and controlled.
Collect requirements	Defining and documenting stakeholder's needs to meet the project objectives.
Define scope	The development of a detail description of the process, project, and product.
Create WBS	Subdividing project deliverables and project work into smaller, more manageable components.
Validate Scope	Formalizing acceptance of the project deliverables.
Control Scope	Monitoring the status of the project and managing changes to the scope baseline.

Because of the nature of Process Automation Systems including thousands of elements is almost impossible to completely define every aspect of these systems before ending the Detailed Design phase or engaging a Main Automation Contractor. This situation could lead to scope creep. As projects continue into the execution phase, the engineering process continues to evolve, i.e. final details are defined. The facility design changes and the automation user requirements are affected. These changes are called

[33] The Project Management Institute (PMI) A Guide to the Project Management Body of Knowledge (PMBOK Guide), Fifth Edition, 2013.

scope creep. To minimize potential scope creep that threatens every automation project, the automation professionals need to have an effective change control process. The need to make sure any change that affects automation, no matter how small, is accompanied by approval in budget, schedule achievability, and any additional risks.[34]

SCHEDULE MANAGEMENT

Project time management includes the processes required to manage timely completion of the project. The Project Time Management processes include[35]:

Define activities: The process of identifying the specific actions to be performed to produce the project deliverables.

Sequence Activities: The process of identifying and documenting relationships among the project activities.

Estimate Activity Resources: The process of estimating the type and quantities of material, people, equipment, or supplies required to perform each activity.

Develop Schedule: The process of analyzing activity sequences, durations, resource requirements, and schedule constraints to project schedule.

Control Schedule: The process of monitoring the status of the project to update the project progress and managing changes to the schedule baseline.

RISK MANAGEMENT

Project Risk Management includes the processes of conducting risk management planning, identification, analysis, response planning, and monitoring and control on a project. The objectives of Project Risk Management are to increase the probability and

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[34] R Teaster, D. Adler, “Successfully Managing Projects”, Intech Magazine (July/August 2013): 28.
[35] The Project Management Institute (PMI), “A guide to the project management Body of Knowledge (PMBOK) Guide”, Fourth Edition, 2008: 129.

impact of positive events, and decrease the probability and impact of negative events in the project.[36]

Project Risk Management is an integral part of project management, as evidenced by the Project Management Institute's A Guide to the Project Management Body of Knowledge (PMBOK Guide) Fourth Edition[37]. Project Risk Management involves following processes:

Plan Risk Management: The process of defining how to conduct risk management activities for a project.

Identify Risks: The process of determining which risks may affect the project and documenting their characteristics.

Perform Qualitative Risk Analysis: The process of prioritizing risks for further analysis or action by assessing and combining their probability of occurrence and impact.

Perform Quantitative Risk Analysis: The process of numerically analyzing the effect of the identified risks on overall project activities.

Plan Risk Responses: The process of developing options and actions to enhance opportunities and to reduce threats to project objectives.

Monitor and Control Risks: The process of implementing risk response plans, tracking identified risks, monitoring residual risks, identifying new risks, and evaluating risk process effectiveness throughout the project.[38]

The Construction Industry Institute (CII) defines constructability as "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives." This emphasizes the importance of

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[36] The Project Management Institute (PMI), "A Guide to the Project Management Body of Knowledge (PMBOK Guide)", Fourth Edition, 2008: 273.
[37] The Project Management Institute (PMI), "A Guide to the Project Management Body of Knowledge (PMBOK Guide)", Fourth Edition, 2008: 273.
[38] The Project Management Institute (PMI), "A Guide to the Project Management Body of Knowledge (PMBOK Guide)", Fourth Edition, 2008: 273.

putting construction insight to work early in project development and integrating that with the conceptual, design and procurement phases to allow for the most efficient, practical and, hence, cost efficient construction techniques.[39] CII claims that adopting a construction focus methodology increases the chance of achieving:

- Reduction in total project cost.
- Accelerated schedule to project completion.
- Enhanced plant maintainability, reliability and operability.
- Selection of fastest designs and construction methods.

The construction stage of any facilities project is where the majority of the project risk occurs (schedule, cost, weather, impacts of new technology/implementation, labor skills, community disputes, etc.). As such, much thought and effort should be expended early in the project so that the most optimum construction methods, techniques and materials are used or specified. [40]

QUALITY MANAGEMENT

Greiman states that there are three elements essential to quality management, defined here. These three elements permeate every industry and have great significance to megaprojects. Without implementing the processes of quality planning, assurance, and control, the project will surely fail.[41]

Quality planning: The process of identifying quality requirements and/or standards for the project and product, and documenting how the project will demonstrate compliance.

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[39] D. Wood, G. Lamberson, S. Mokhatab, "Project execution risk management for addressing constructability", Hydrocarbon Processing (December 2008): 35.
[40] D. Wood, G. Lamberson, S. Mokhatab, "Project execution risk management for addressing constructability", Hydrocarbon Processing (December 2008): 35.
[41] V. Greiman, "Megaproject Management, Lessons on Risk and Project Management from the Bid Dig", John Wiley & Sons, 2013: 319.

Quality assurance: The process of auditing the quality requirements and the results from quality control measurements to ensure appropriate quality standards and operational definitions are used.

Quality control: The process of monitoring and recording result of executing the quality activities to assess performance and recommend necessary changes.

Quality and consistency is one the most important aspects to success in the design of Process Automation Systems in industrial megaprojects. Because of millions of pieces of information generated by the design of Process Automation Systems in megaprojects, quality and consistency cannot be achieved without a common software engineering platform and well established specifications and work practices. It is difficult for engineering offices to staff projects at a single location with the number and size of megaprojects. To meet this need engineering companies are sharing the work with their offices around the world.

Process Automation Systems Design and Implementation

HOW PROCESS AUTOMATION SYSTEMS WORK?

Process Automation Systems in the Oil & Gas Industry are based on interconnected sensors, controllers, operator workstations and actuators. All Process Automation Systems require knowledge of process conditions in order to take control action and to display the process conditions to the operator. Process sensors provide a signal to the Process Automation System that represents the physical state of the process. The control function determines the action necessary to control the process and sends this information to the actuator of the final element. Field devices (sensors and actuators) communicate with the control system through different means based on accuracy requirements, available technology, and ease of installation, range of operation, security, reliability and response requirements.[42]

Process Automation Systems execute continuous or non-continuous control functions. Continuous regulatory control functions execute on a user defined interval. Non-continuous regulatory control functions execute upon events such as an operator action, process condition, alarm or some other event. Non-continuous regulatory control functions include logic control, sequential control and batch control. Figure 8 illustrates the functions of typical Process Automation System; these functions may be organized differently depending upon the actual hardware and software used.[43]

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[42] API Recommended Practice 554 Part 1, "Process Control Systems – Process Control Functions and Functional Specification Development", Second Edition, July 2007: 17.
[43] API Recommended Practice 554 Part 1, "Process Control Systems – Process Control Functions and Functional Specification Development", Second Edition, July 2007: 17.

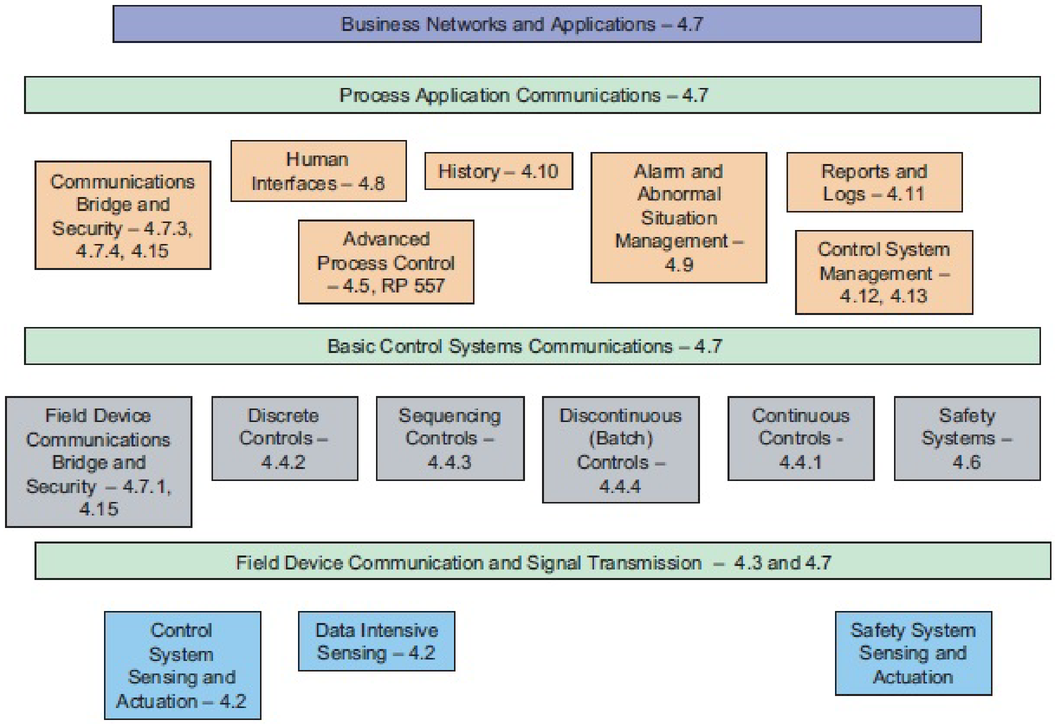

Figure 8: Process Automation System (PAS) Functions[44]

DESIGN AND IMPLEMENTATION OF PROCESS AUTOMATION SYSTEMS

There are several types of systems that may be used as part of a Process Automation System. Historically Process Automation System were implemented using a combination of a proprietary DCS that handled most continuous control functions and potentially several specialty sub-systems, often provided by third parties, which would handle functions that the Distributed Control System (DCS) was not able to perform. Examples of these sub systems are PLCs, safety logic solvers, analyzers and equipment

[44] API Recommended Practice 554 Part 2, "Process Control Systems – Process Control System Design", First Edition, October 2008: 2.

monitoring systems. Usually these sub systems require additional hardware and software to interface them with the Distributed Control System (DCS). . The design of the Process Automation System will depend of the type of project and the end customer needs.

The design criteria of Process Automation Systems should address the following aspects:[45] the interconnection of hardware components including the hierarchy, location, type of connections among different nodes in the system network, the electrical requirements, the number of elements in the network at level 1 through 4 of the Hierarchical Computer Control Structure for a large Manufacturing Complex (shown on figure 3), the safety instrumented system requirements, the interfaces with other complex systems and operating and maintenance communication systems.

Physical configuration and space requirements of the Process Automation System to install must be defined. When implementing Process Automation Systems the design shall define the general physical layout of the system including the location and approximate layout and size of control centers and satellite control houses, field enclosures and other equipment. The physical layout of the system is based on the approximate equipment requirements, including the number and sizes of operator HMIs, requirements and locations for engineering stations and the number and sizes of control equipment cabinets or other enclosures, including the approximate numbers of control modules and I/O modules and associated accessory equipment. Process Automation Systems in megaprojects would typically require special applications demanding high level computer resources, for which the designer shall establish the number and location of higher level computers or other control computing resources and the number and location of computing resources required to support other business functions.

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[45] API Recommended Practice 554 Part 2, "Process Control Systems – Process Control System Design", First Edition, October 2008: 18.

Process Automation Systems are considered mission critical systems within the Oil and Gas Industry to operate processes in safe and efficient way; as such they require a high level of availability. A reliable electrical power supply system shall be integrated to the design; the engineer shall define the power supply system and distribution requirements including AC and DC power supply redundancy requirements. From the electrical prospective, the design of Process Automation Systems shall include lightning protection and grounding systems to protect the operating personnel and hardware.

The topology of the Process Automation System should cover interconnection requirements between control building and the field. With the advance on industrial network communication technologies and industrial protocols consolidated control schemes of Oil & Gas facilities are now possible. Organizations are opting for centralized control buildings, where it is important to establish the requirements for hardwired connections from the process control console to the units or remote instrument buildings. This include items such as connections to hardwired shut down switches, dedicated alarms or other dedicated functions.

Operator Training Systems help to achieve a more effective handover of the system to operations personnel. The engineer should define the location and installation of development or test hardware and software to support software upgrade testing and development of new or modified control applications during the Process Automation System life cycle. This leads to the need of supplying Operator Training Systems including simulation packages and hardware for testing purposes as integral part of the Process Automation Systems. Provision for control of hardware and software maintenance/upgrades, configuration changes, process equipment changes, operator certification and re-certification, emergency preparedness, and vendor support the process control equipment and the process equipment.

PAS communication network specifications shall be set to support the implementation of Process Automation Systems. To develop these networks the engineer must specify the types, general layout and routing of field buses and other communications connections with field instrumentation and systems, the types, general layout and routing of process control and business communications networks. This includes peer to peer process control communications, hierarchical communications, field networks and business networks.

One important sub system of the Process Automation System is the Safety Instrumented System (SIS). Safety Instrumented Systems are designed to monitor the process and control outputs in order to prevent or mitigate hazardous events. The engineer should define the requirements such as integrated or independent hardware and software and the required communications.

Part of the Process Automation System are some special subsystems for which interfaces must be defined before the execution phase, interfaces with other complex systems such as analyzers, machine monitoring or other similar applications in megaprojects.

Finally to operate and maintain Oil & Gas facilities communication systems should be defined by the Automation Lead Engineer including in the design the requirements for systems such as radio, telephone and video.

TYPICAL PROCESS AUTOMATION SYSTEM DESIGN DELIVERABLES

Figure 9 depicts the flow of a typical multidiscipline chemical process design project from the point of view of the Process Automation System.[46]

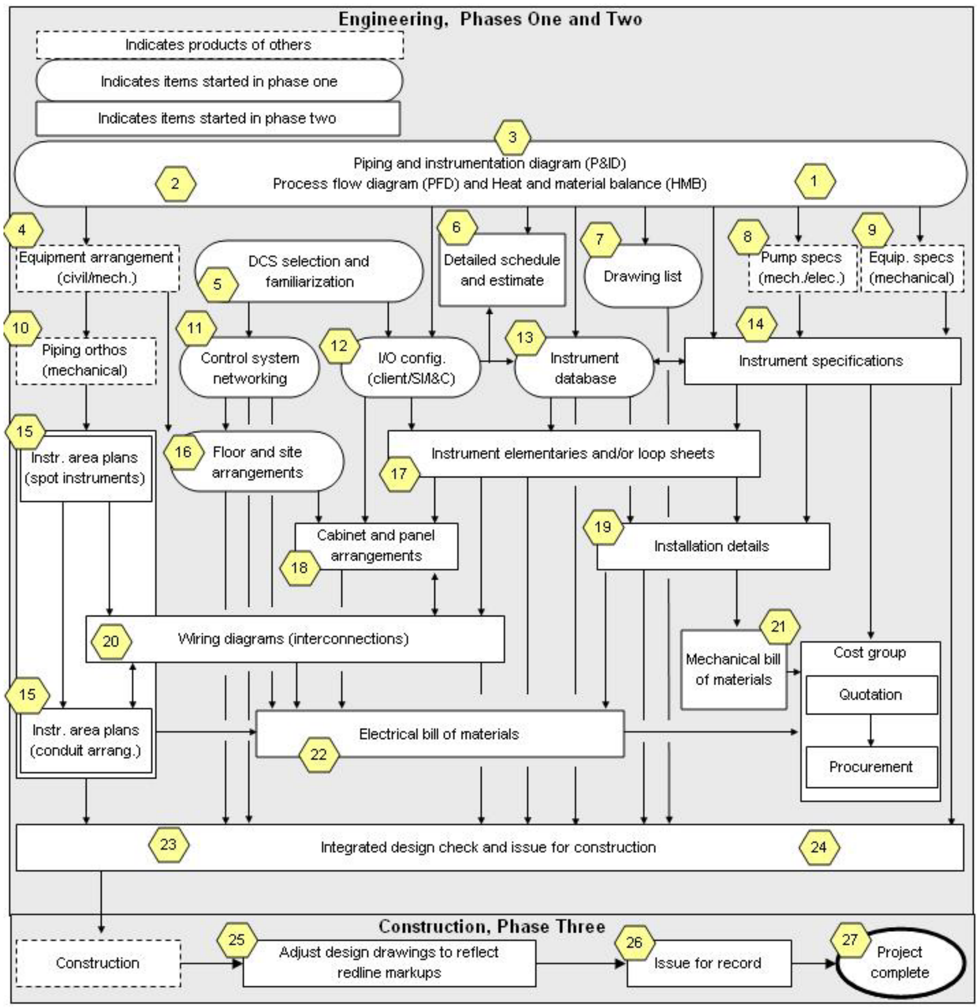

Figure 9: Typical Process Automation System project flow diagram.[47]

The design package shown includes following deliverables or products: Process Flow Diagrams, Heat and Material Balance, Piping and Instrumentation Diagrams

[46] M. Whitt, "Successful Instrumentation and Control Systems Design". Research Triangle Park, NC, 2004.
[47] M. Whitt, "Successful Instrumentation and Control Systems Design". Research Triangle Park, NC, 2004: 20.

(P&ID), Equipment Arrangements, DCS Selection, Detailed Estimate and Schedule, Drawing List, Equipment Specifications, Piping Orthographic Drawings, Control System Interconnection Drawing, I/O Configuration, Instrument Database, Instrument Specifications, Site and Floor Plans, Control Room and I/O Termination Room Arrangements, Instrument Elementary Wiring Diagrams and Instrument Loop Diagrams, Panel Arrangements, Installation Details, Wiring Diagrams, Mechanical and Mounting Bill of Materials, Electrical Bill of Materials, Integrated Design Check, Issue for Construction, Red line drawings, Issue for Record, project wrap up or close out document. The diagram also gives graphic evidence of the importance of the Piping and Instrumentation Diagrams (P&IDs) to the Automation design process. The P&ID is ultimately the basis for the entire Process Automation design package. It is a living record of the automation system from the sensing elements through the computer system to the final control elements.

WHY IMPLEMENTING PROCESS AUTOMATION SYSTEMS IS SO CHALLENGING?

The typical automation system is complex and includes a wide array of technologies, including field instrumentation, computer system hardware, software applications, and data management. It is difficult to master one component of automation technology in a life time, much less become an expert on all the diverse and rapidly evolving technologies needed to control manufacturing facilities today. The lead automation engineer is usually assigned to manage automation projects, but the skills required for project success are significantly wider than technical expertise. The skills of planning, organizing, motivating, and managing resources are needed just as much as deep technical expertise on an automation project. The proven way to improve the automation team's odd of success is to use project management tools and processes.[48]

The quantities of instrumentation and control entities part of the Process Automation System are 2 to 3 orders of magnitude higher than the numbers of equipment. For example, a facility that has 1000 pumps, compressors, vessels, etc., may have 100,000 to 400,000 instruments.[49]

WHY PROCESS AUTOMATION SYSTEMS PROJECTS FAIL?

According to Russell Griffith with Chevron Energy Technology Company (ETC) Process Automation Division, common automation related problems that have historically plagued large projects are: inability to clearly define automation system requirements; lack of project planning leading to poor execution; continuous changes or scope creep throughout project execution; unforeseen special skill-set resource needs; design inconsistencies and lack of single point for interfaces between project discipline team; inadequate vendor package interface definition leading to improper integration with control system during engineering phase and poor as built documentation and not maintaining Instrument Index post commissioning.[50]

[48] R Teaster, D. Adler, "Successfully Managing Projects", Intech Magazine, July/August 2013 :28-34

[49] API Recommended Practice 554 Part 2, "Process Control Systems – Process Control System Design", First Edition, October 2008.

[50] Griffith, Russell. "Chevron's use of the Main Automation Contractor Strategy to Deliver Global Standardization", ARC Forum, February 10, 2010.

Best Practices for implementing Process Automation Systems

Sandy Vasser member of ExxonMobil Development division presented following aspects of Process Automation Systems implementation in capital projects at the ARC World Industry Forum on February of 2010 to improve the Automation execution programs; enhance identification of all automation resources and roles throughout the lifecycle of a project; ensure understanding of project deliverables, team members responsibilities and timing; develop foundation for consistency that allows flexibility based on project specifics and improve handover to operations.

AUTOMATION EXECUTION PROGRAM

- Develop Automation System Execution Philosophy; transition to Automation Execution System Plan by the Front-end engineering design (FEED) phase.
- Execution plan covers all automation activities (e.g. design, construction, commissioning, and start-up) and all resources from FEED through start-up.
- Develop specific tools to address specialty areas like third party package integration, commissioning and brown field considerations.

ASSESS AUTOMATION TEAM MEMBERS

- Ensure the Project Automation Coordinator has the proper authority.
- Include subject matter expert support where required.
- Early identification of all major third party packages and required interface strategy.

- Early identification of all special focus areas like networking configurations, cyber security and alarm management.
- Develop roles and titles and apply consistent personnel terminology in key documents.

DEVELOP ROAD MAP

- Develop Automation Execution "Road Map" that identifies all deliverables from specifications and contract documents.
- Establish interface agreements for all deliverables between all parties.
- Roadmap and interface agreements assign deliverable responsibility utilizing previously defined terms and roles.
- Roadmap and interface agreements define timing of deliverable and interdependencies between activities.

DEVELOP FOUNDATION FOR CONSISTENCY

- Tailor common tools, processes and scope assignments to project to mitigate risks.
- Assess capabilities of all participants; identify strengths, weaknesses; make assignments based on "best resource fit".
- Ensure flexibility on contract terms to allow shifts of scope between contractors as project constraints, project participant's skills and project details become better known.

DEVELOP TRANSITION PLANS

- Support earliest possible inclusion of Instrumentation and Control Operations representatives into the Project Team.

- Obtain approval from operations for the design basis and philosophies.
- Follow management of change for deviations to these approved documents.
- Prepare operations for taking ownership by involving them in the FAT (Factory Acceptance Test) and SAT (Site Acceptance Test).
- Resource commissioning with operations to develop ownership and ease transition.
- Establish long-term service agreement with Automation Provider to facilitate support post start up.

One of the mayor players in the industry of Automation Systems, Honeywell with its Automation & Control Solutions' division, suggests taking an integrated approach to automation projects execution[51]. In this approach, Honeywell applies its knowledge to integrate project management, operations, automation, information management, security and maintenance all in a safe and secure environment. The following are key factors to achieve success in the execution of the Automation scope in Megaprojects based on Honeywell experience performing the role of Main Automation Contractor:

- Reduction in Project Risk through in depth project planning that addresses contracting issues, technology and resource planning and scope definition.
- Design Consistency across large multiple EPC projects, multiyear phased projects, and multiple facilities globally.

[51] Honeywell White Paper, "Integrated Main Automation Contractor (I-MAC) for Refining", November 2007.

- Project Cost Savings through utilization of efficient and proven system designs and practices.
- Operational Readiness by integrating operator effectiveness philosophies, timely operator training and operating procedures into the overall automation system design.
- Business Readiness by early identification of business system requirements and ensuring the data available in the automation system is transformed into useful knowledge to support the business.
- Lifecycle Efficiency that addresses technology obsolescence, support requirements and management across the entire automation scope including instrumentation, controls, optimization, training, security, production management and business systems.

The benchmarking research conducted by Raymond Teaster and Dave Adler reveals that successful automation projects have common characteristics: good upfront planning, strong support from operations leaders during implementation, an understanding of the work processes, the ability to define key user requirements, schedule and budget management, deliverable and key project event monitoring, and the skilled automation professionals required to start up and execute the project. Understanding and adapting traditional project management tools and approaches to automation is the only way to ensure these characteristics are all delivered. [52]

Teaster and Adler research highlights ways to achieve project goals: creating a robust scope, effective schedule development and project cost prediction. The first step in developing a scope is to understand the business drivers and justification for the

[52] R Teaster, D. Adler, "Successfully Managing Projects", Intech Magazine, July/August 2013: 28.

investment in automation. The next step is the automation philosophy. The scope document also clearly defines those items that are out of the scope.

As the project continues into the execution phase, the engineering process continues to evolve. The facility design changes and the automation user requirements are affected. The closer the project gets to start up, the more the operations folks and process engineers will worry about the overall design. These changes are called scope creep. To minimize potential scope creep that threatens every automation project, the automation professionals need to have an effective change control process. They need to be prepared to just say "not in scope". Or they need to make sure any change that affects automation, no matter how small, is accompanied by approval for a change in budget, schedule, achievability, and any additional risks.[53]

The project schedule answers the question, "How and when are we going to do it?"[54] The project schedule communicates the intended plan for the project and where the project is in that plan. A well-developed schedule is a logical representation of the project plan and proof that the objective is possible. The schedule is also the project manager's best tool in evaluating the impact of changes to the project. The act of developing the schedule helps to reveal dependencies from inside and outside the project and identifies potential risks to the project. A feature of automation projects that makes them difficult is the work processes can vary depending on the facility's operational strategy (continuous vs. batch), level of automation, and control system (PLC vs. DCS).

Keeping the project schedule current is essential to successfully managing a project. Regular project schedule reviews help team members understand how their work fits together and why it is important to complete tasks on time. The schedule is an

[53] R Teaster, D. Adler, "Successfully Managing Projects", Intech Magazine, July/August 2013: 29.
[54] R Teaster, D. Adler, "Successfully Managing Projects", Intech Magazine, July/August 2013: 30.

essential tool to communicate the project plan and to build the confidence of the project team and management that the project is under control and headed for success.[55]

[55] R Teaster, D. Adler, "Successfully Managing Projects", Intech Magazine, July/August 2013: 32.

FEL practices for successful process automation systems in Megaprojects

FEL (front-end loading) as discussed in chapter 2, refers to the work process needed to prepare a project for execution. FEL with its three phases: business case development (FEL-1), scope development (FEL-2), and project definition and planning (FEL-3) is the single most important predictive indicator of project success. Megaprojects in the Oil & Gas Industry will always present challenges for Process Automation Systems including tight project schedules, capital funding constraints, project interface and technical complexities with multiple EPCs. Following FEL practices will allow the execution phase (implementation) of Process Automation Systems to be on or close to its approved budget and schedule and should perform as promised after startup of new facilities built in megaprojects.

The first gate at the end of FEL-1 is designed to produce an inspection and evaluation of the health of the business case. [56] Even though Process Automation Systems are not subject to evaluation in FEL-1, its development in FEL-2 and FEL-3 shall be strategically aligned with the business case evaluated in FEL-1.

FEL-2 develops and articulates the scope of a project to a point where we can be confident that all elements of scope are accounted for.[57] Process Automation System Design Engineers must ensure that after work is complete in FEL-2, a satisfactory response can be given to the question: Is the Scope complete? The engineer must not forget that a robust and well defined scope will avoid scope creep and change orders throughout project execution. In FEL-2 first define the automation philosophy for your

[56] Merrow, Edward. “Industrial Megaprojects: Concepts, Strategies, and Practices for Success”. Chicago: Wiley John Wiley & Sons, Inc, 2011: 203.
[57] Merrow, Edward. “Industrial Megaprojects: Concepts, Strategies, and Practices for Success”. Chicago: Wiley John Wiley & Sons, Inc, 2011: 206.

megaproject. Based on the Automation Philosophy the sub systems that will be part of the Process Automation System must be selected. One should remember that all you are doing in FEL-2 is to be prepared to embark in FEL-3. FEL-3 should have clear and solid inputs from FEL-2 to develop the scope. To achieve that goal once the scope is defined, the standards or job specifications for each subsystem must be prepared and approved to develop the scope in FEL-3. Job specifications will provide the foundation to develop the scope in FEL-3.

A well-defined Process Automation System early in FEL-2 will support an accurate estimate based on known information. Assuming that the project team makes available a good set of Process Flow Diagrams and experience from similar projects is available, the designer should produce a first full factored project estimate of the Process Automation System. From this point on the project the automation engineer should monitor and control the cost growth and cost index of the Process Automation System. A controlled cost growth and cost index of the Process Automation System will contribute to success of the megaproject you are working on.

One important factor to consider in FEL-2 is the global environment in which FEL is implemented in megaprojects. The fact is that in many cases FEL-3 in megaprojects is executed in a global work environment, with multiple EPC contractors or one EPC with multiple engineering centers located at different geographic and time zones. All engineering software tools to support the execution of FEL-3 must be selected, for example many international engineering companies have established the use of SmartPlant Instrumentation Software from Intergraph as the standard engineering tool to support the design phase of Process Automation Systems. Due to the millions of pieces of information that the Process Automation System design will generate in FEL-3 and in the execution phase, the selection of the software platform able to handle the data to support the design, should be a must do task in FEL-2. After selecting the software platform, engineers shall define the execution model and practices to use it.

The question to ask at the end FEL-3 is the project ready to execute? To provide a positive answer to the question, all recommendations after an integrated design check must be completed by the design team. The integrated design check must evaluate consistency, job specifications compliance, quality, cost growth and cost index. Since FEL-3 is all about getting prepared to execute the megaproject, it is very important from the Project Management perspective that for the Process Automation System a project execution plan is available and it is approved. The project execution plan must include the contracting strategy and a well develop schedule for the Process Automation System. Never leave these items for the execution phase because you will be falling into one of the seven key mistakes that make megaproject fail so often: “Don’t worry; we’ll work out the details of the deal later”.[58] There is no doubt that during the execution phase one of the scarcest resources is time.

During FEL-3 Automation Engineers shall strive for design consistency and efficiency. Enforcement of automation standardization achieves consistency in the design by utilizing the same job specifications, design and engineering database applications across the project with all engineering centers involved in a megaproject. Even though job specifications are set and defined in FEL-2, the Automation Lead Engineer should train and inform the design teams on their application. Common work practices should be established to implement the specifications in a consistent way. This seems to be a straightforward task but in reality is one of the most difficult objectives for Process Automation Systems in megaprojects.

[58] Merrow, Edward. “Industrial Megaprojects: Concepts, Strategies, and Practices for Success”. Chicago: Wiley John Wiley & Sons, Inc, 2011:3.

Selection of contracting strategies for Main Automation Contractors, Integrated Control and Safety System Contractors or Main Instrumentation Vendors must be established. The Automation Engineer must develop a well-structured contracting strategy, a plan to execute the project. Never get to execution to try to define your contracting strategy. Valuable time can be wasted trying to define the contracting strategy in the execution phase, many things can change in the execution phase except for mechanical completion and startup dates. If the time approved and promised for execution is not used efficiently, the project will suffer in quality when project teams commit to unrealistic schedules.

Process Safety Management is an area where the Automation Lead Engineer must take a careful and a systematic approach in FEL-3. To implement Safety Instrumented Systems design according to latest functional safety international standards for the process industry is not an easy task. The implementation of a Safety Instrumented System (SIS) must be led by experts in the systematic approach required by standards. Despite that many project management teams do not understand or do not appreciate the importance of such methodologies, the Automation Lead Engineer must inform the project team of its importance and liability involved in SIS systems. Only by applying a committed and thorough approach to Safety Instrument Systems following the industry standards such as IEC-61511[59], in particular its Safety Life Cycle, successful implementations can be achieved.

All technologies and configurations of field instrumentation must be established and developed in the project Piping and Instrumentation Diagrams in FEL-3. The Automation Lead Engineer must define in the Piping and Instrumentation Diagrams all instrument types; select the instrumentation technology according to the job

[59] IEC 61511 International Standard, Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements - First Edition, November 2004.

specifications and establish the control strategies in a particular process unit. The instrumentation type selection should be done in FEL-3; transferring this responsibility to the execution phase will open a door for potential change orders and inappropriate interpretation of specifications. For instrumentation related to process safety the Automation Lead Engineer should take the scope development up to a point where the proposed configurations meet the safety integrity levels required by safety analysis conducted in FEL-3.

The Automation Lead Engineer must develop a project execution plan and effective schedule in FEL-3. This should be done by identifying all automation related activities early and developing a workable project plan for execution. The execution plan to implement the Process Automation Systems should be approved and there should be full agreement with management, operations and maintenance groups that the proposed execution will meet the project budget, schedule, scope and quality.

One of the aspects cited throughout this research is the management of change, during the development of the scope during FEL. Management of change practices must be set and understood by all stakeholders during the FEL work flow. All stakeholders must be committed to follow a management of change policy whenever a change, variation or deviation is proposed, detected or submitted for approval. When introducing changes in FEL-3 to the scope defined in FEL-2, every stakeholder must evaluate if the change adds value or is really worth from the perspective of project budget, schedule, scope and quality. This evaluation as clear as it is proposed is not always fully done. Process Automation Projects suffer terrible when these situations are permitted.

Finally during all phases of FEL the Automation Design Engineer must recognize the importance of being aware and monitor the Key Performance Indicators (KPIs) used to measure success in Megaprojects: Cost growth, Cost index, Schedule index, Schedule slippage; and Operability index which will be effectively measured after startup and within months of operation of the facilities built. Activities to reduce the Project Risk through in depth project planning that addresses contracting issues, technology and resource planning and scope definition must be promoted. Automation team members should understand and adapt traditional project management tools and approaches to control the schedule, cost, budget and quality. More training has to be done for Automation professionals in the Project Management arena to effectively deliver successful Process Automation Systems. “Project Management should not be considered a noble art that only project managers and engineers practice, but rather a tool that every project member -including novice engineers – should understand and apply to daily project work.”[60]

[60] D.W. Choi, Understanding basic project management, Practice the four basic elements to ensure a successful outcome, Hydrocarbon Processing, December 2008: 65-68.

Conclusions

With natural gas production continuing to gain momentum and the steady oil prices in the world market, is likely that in the oil and gas industry more Megaprojects will be execution in the years to come. Megaprojects have an important impact in societies but have shown statiscally that as projects they are not always successful endeavours when key performance indicators (KPIs) such us cost growth, cost index, execution schedule index, execution schedule slip and production index are examined. The failure rates for these projects reported in the existing literature is alarming. These KPIs should be understood and carefully managed by stakeholders during FEL and execution phases of megaprojects.

The systematic approach in FEL used to prepare for the execution of megaprojects, must be understood and enforced by Automation Lead Engineers utilizing traditional tools of Project Management. The skills of planning, organizing, motivating and managing resources are critical and needed just as much as deep technical expertise to deliver successful Process Automation Systems in Megaprojects. At the end of FEL-2 (scope definition phase) and FEL-3 (scope development phase), Automation Lead Engineers must conduct an integrity check to ensure that the budget, schedule, scope and quality in the next phase of the project will meet the project business objectives.

Process Automation Systems in the Oil and Gas industry represent a key piece of the puzzle for the safe and efficient operation of new facilities built in megaprojects. Process Automation Systems include several subsystems and thousands of field sensors. This research focussed on practices to increase the probability of success in the implementation of Process Automation Systems in megaprojects, it was done when the author was participating as the Automation Lead Engineer in a refinery expansion megaproject. It is clear that the lessons learned in previous implementations of Process Automation Systems in megaprojects suggest that more work needs to be done to achieve a higher level of completeness of FEL at authorization.

The Automation Lead Engineer must realized the complexity of implementing Process Automation Systems in tight schedules for these large projects. During FEL millions of pieces of information are produced and execution phases are planned in a global environment with multiple EPCs. This creates a challenging journey, in which commitment to project business objectives and a clear management of change policies should allow the Automation Lead Engineer develop comprehensive execution plans, process automation system philosophies, complete system specifications, robust scopes and effective schedules to deliver successful Process Automation Systems.

Glossary

EPC refers to engineering, materials procurement, and construction the three principal activities required to create a capital project. EPC also refers to the industry that provides these three activities to capital projects. These firms in the EPC industry are called contractors. In addition, EPC refers to a form of contracting for engineering, procurement and construction services that has all three activities performed by a single contracting company or by a single consortium of contractor companies.

FAT refers to Factory Acceptance Test, is a test conducted to determine if the requirements of a specification or contract are met. It may involve chemical tests, physical tests, or performance tests.

FEED stands for front-end engineering design. This term is used primarily by the oil and chemical industries for the third phase of FEL.

FEL stands for front-end loading. This term refers to the work process needed to prepare a project for execution. FEL is generally organized into three phases: business case development, scope development, and project definition and planning.

IPA stands for Independent Project Analysis, Inc., a global research and consulting company devoted exclusively to the understanding of capital projects and capital project delivery organizations in the petroleum, chemicals, minerals, pharmaceutical and power industries.

WBS is deliverable oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables, with each descending level of the WBS representing an increasingly detailed definition of the project work. The WBS organizes and defines the total scope of the project, and represents the work specified in the current approved project scope statement. The planned work is contained within the lowest level WBS components, which are called work packages. A work package can be scheduled, cost estimated, monitored, and controlled.

SAT refers to Site Acceptance Test, is test conducted at the project job site to determine if systems are ready for startup and normal operation after mechanical installation completion.

Bibliography

[1] Merrow, Edward. "Industrial Megaprojects: Concepts, Strategies, and Practices for Success". Chicago: Wiley John Wiley & Sons, Inc, 2011.

[2] Miller, Roger and Lessard, Donald with the participation of Serghei Floricel and the IMEC Research Group. "The Strategic Management of Large Engineering Projects: Shaping institutions, Risks and Governance". United States of America: Massachusetts Institute of Technology, 2000.

[3] Lamberson, G., Wood D., S. Mokhatab. "Project execution risk Management for addressing constructability". Hydrocarbon Processing, December 2008: 35.

[4] Lavingia, N. "Business success through Excellence in Project Management (Better, Cheaper, Faster and Safer Projects)".

[5] Vasser, Sandy. "Automation Systems Execution Learnings", ARC World Industry Forum, February, 2010.

[6] Griffith, Russell. "Chevron's use of the Main Automation Contractor Strategy to Deliver Global Standardization", ARC Forum, February 10, 2010.

[7] El-Reedy, Mohamed. "Construction Management for Industrial Projects – A Modular Guide for Project Managers". Salem, MA: Scrivener Publishing LLC, 2011.

[8] Lipták, Béla. "Process Control and Optimization – Instrument Engineer's Handbook Fourth Edition, Volume II". Boca Raton: CRC Press, 2006.

[9] The Project Management Institute (PMI), "A guide to the project management Body of Knowledge (PMBOK) Guide", Fourth Edition, 2008.

[10] B. Flyvbjerg, N. Bruzelius and W. Rothengatter, "Megaprojects and risk: anatomy of ambition". Cambridge: Cambridge University Press, 2003.

[11] M. Whitt, "Successful Instrumentation and Control Systems Design". Research Triangle Park, NC, 2004.

[12] R Teaster, D. Adler, "Successfully Managing Projects", Intech Magazine (July/August 2013): (28-34).

[13] Choi, D.W., "Understanding basic project management", Hydrocarbon Processing Magazine (December 2008): 65-68.

[14] V. Greiman, "Megaproject Management, Lessons on Risk and Project Management from the Bid Dig", John Wiley & Sons, 2013.

[15] Honeywell Service Note, "Integrated Main Automation Contractor Concept and FEED Services", Dec 2007.

[16] Honeywell White Paper, "Integrated Main Automation Contractor (I-MAC) for Refining", November 2007.

[17] The Project Management Institute (PMI), "A Guide to the Project Management Body of Knowledge (PMBOK Guide)", Fifth Edition, 2013.

[18] D. Wood, G. Lamberson, S. Mokhatab, "Project execution risk management for addressing constructability", Hydrocarbon Processing (December 2008): (35-42).

[19] J. Richard Capka, "Megaprojects – They Are a Different Breed", Public Roads Magazine, Jul/Aug Vol 68 No 1, 2004, http://www.fhwa.dot.gov/publications/publicroads/04jul/01.cfm

[20] R. Alston, "Process Control Networks: Secure Architecture Design", Honeywell, 2013.

[21] ANSI/ISA-95.00.01-2000, "Enterprise-Control System Integration Part 1: Models and Terminology", July 2000.

[22] Bechtel, "Jamnagar Refinery", May 2007, http://www.bechtel.com/jamnagar_refinery_expansion.html.

[23] BP, "Whiting Refinery Modernization Project", http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/W/WRMP.pdf

[24] API Recommended Practice 554 Part 1, "Process Control Systems – Process Control Functions and Functional Specification Development", Second Edition, July 2007.

[25] API Recommended Practice 554 Part 2, "Process Control Systems – Process Control System Design", First Edition, October 2008.

[26] IEC 61511 International Standard, Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements - First Edition, November 2004.

Vita

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